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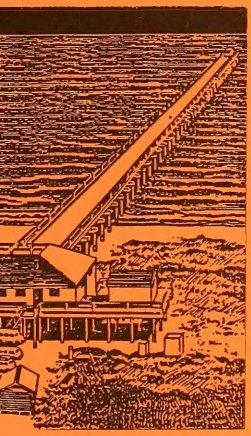

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REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CO-3

CASE HISTORIES OF CORPS BREAKWATER AND JETTY STRUCTURES

Report 8
LOWER MISSISSIPPI VALLEY DIVISION

by

Francis E. Sargent, Robert R. Bottin, Jr.

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Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32278 and Work Unit 31269

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	Problem Area		Problem Area
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
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COVER PHOTOS:

TOP — Field Research Facility, Duck, North Carolina.

BOTTOM — View of East Jetty at South Pass, South Pass, Louisiana.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report REMR-CO-3	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES, Coastal Engineering Research Center 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39181-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. See reverse

11. TITLE (Include Security Classification)
Case Histories of Corps Breakwater and Jetty Structures; Report 8: Lower Mississippi Valley Division

12. PERSONAL AUTHOR(S)
Sargent, Francis E.; Bottin, Robert R., Jr.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Report 8 of a series	FROM Feb 86 TO Jul 86	January 1989	55

16. SUPPLEMENTARY NOTATION A report of the Coastal Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
See reverse

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is eighth in a series of case histories of US Army Corps of Engineers (Corps) breakwater and jetty structures at nine Corps divisions. Herein, case histories are presented for 10 jetty structures located within the US Army Engineer Division, Lower Mississippi Valley (LMVD), which encompasses the gulf coast of Louisiana. Presently, there are approximately over 153,000 lin ft of jetty structures managed by LMVD. These structures are predominantly of rubble-mound construction. Seven of the projects have undergone repair and/or modification during their lifetimes. Most of this work has consisted of placing additional stone to bring structures up to grade. Subsidence of structures, due mainly to unconsolidated silts and clays of the underlying foundation, appears to be the principal cause of deterioration. In particular, the jetties at Southwest Pass have a very extensive repair history.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

10. SOURCE OF FUNDING NUMBERS (Continued).

Work Unit 32278 and Work Unit 31269.

18. SUBJECT TERMS (Continued).

Breakwater	REMR (Repair, Evaluation, Maintenance,
Concrete armor units	and Rehabilitation)
Jetty	Rubble-Mound structures

PREFACE

This report was prepared as part of the Coastal Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was carried out jointly under Work Unit 32278, "Rehabilitation of Rubble-Mound Structure Toes," of the REMR Program and Work Unit 31269, "Stability of Breakwaters," of the Civil Works Coastal Area Program. For the REMR Program, Coastal Problem Area Monitor is Mr. John H. Lockhart, Jr., Office, Chief of Engineers (OCE), US Army Corps of Engineers (Corps). REMR Program Manager is Mr. William F. McCleese of the US Army Engineer Waterways Experiment Station's (WES's) Structures Laboratory, and Coastal Problem Area Leader is Mr. D. D. Davidson of WES's Coastal Engineering Research Center (CERC). Messrs. John G. Housley and Lockhart, OCE, are Technical Monitors of the Civil Works Coastal Area Program.

This report is eighth in a series of case histories of Corps breakwater and jetty structures at nine Corps divisions. The case histories contained herein were extracted from information obtained from several sources (where available) which included inspection reports, conferences, telephone conversations, project plans and specifications, project files and correspondence, design memorandums, literature reviews, model studies, surveys (bathymetric and topographic), survey reports, annual reports to the Chief of Engineers, House and Senate documents, and general and aerial photography. Unless otherwise noted, only prominent changes to the prototype structures subsequent to March 1985 are included in this report.

This work was conducted at WES during the period February to July 1986 under general direction of Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and under direct supervision of Mr. C. Eugene Chatham, Jr., Chief, Wave Dynamics Division (CW), and Mr. D. D. Davidson, Chief, Wave Research Branch (CW-R), CW. This report was prepared by Messrs. Francis E. Sargent and Robert R. Bottin, Jr., CW, and typed by Ms. Myra Willis, CW. This report was edited by Ms. Shirley A. J. Hanshaw, Information Products Division, Information Technology Laboratory, WES.

COL Dwayne G. Lee, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.76458275	cubic metres
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds per square foot	4.882428	kilograms per square metre
pounds per cubic foot	16.01846	kilograms per cubic metre
square yards	0.08361274	square metres
tons (2,000 lb, force)	8806.443353	newtons

CASE HISTORIES OF CORPS BREAKWATER AND JETTY STRUCTURES
LOWER MISSISSIPPI VALLEY DIVISION

PART I: INTRODUCTION

Background

1. The US Army Corps of Engineers (Corps) is responsible for a wide variety of coastal structures located on the Atlantic, Pacific, and gulf coasts, the Great Lakes, the Hawaiian Islands, other islands, and inland waterways. Coastal improvements such as breakwaters or jetties are necessary to provide harbor protection and the safe passage of vessels. These structures are subjected continuously to wave and current forces and usually are constructed on top of movable-bed materials. Under these conditions structural deterioration may occur and, at some point, maintenance, repair, or rehabilitation may be required when the structure deteriorates and/or fails to serve the existing needs of the project. Some projects have been maintained for 150 years or more. Methods of construction and repair have varied significantly during this time, due principally to a better understanding of coastal processes, availability of construction materials, existing wave climates, regional construction practices, and economic considerations.

Purpose

2. The purposes of this report are to provide insight into the scope, magnitude, and history of coastal breakwaters and jetties under Corps jurisdiction; to determine their maintenance and repair history; to determine their methods of construction; and to make this information available to Corps personnel. To accomplish these objectives, case histories of Corps breakwater and jetty structures have been developed to quantify past and present problem areas (if any), to take steps to rectify these problems, and to subsequently evaluate the remedial measures. General design guidance can be obtained from the solutions that have been most successful during selection of repair techniques for other structures. Information in this report should be of particular value to Corps personnel in the US Army Lower Mississippi Valley Division (LMVD) and its coastal districts, and possibly to non-Corps

personnel. Further research is being conducted to address problems where adequate solutions are lacking or where specific guidance is required (i.e. general armor stability, toe protection, localized damage, use of dissimilar armor, wave runup, and overtopping).

PART II: SUMMARY OF CORPS BREAKWATER AND JETTY STRUCTURES IN LMVD

3. There are 10 projects within LMVD which contain 19 jetty structures (Figure 1). There are no breakwaters. All projects are located on the Gulf of Mexico, and of these, eight are situated near the mouth of the Mississippi River (Figure 2). With the exception of the single jetty at Grand Isle, all projects have dual jetties. There is a total length of over 153,000 lin ft of jetty structures. All of these are rubble mound (stone and/or shell) in cross section, with the exception of the jetties at South and Southwest Passes, which have been supplemented with concrete caps on several occasions since original construction. Concrete capping has not been used recently and is not expected to see future use due to its higher cost compared with stone. The structures typically have been built on unconsolidated silts and clays which exist throughout the area to depths of several hundred feet. Most of the structures are located in water depths of less than 10 ft*. (The seaward ends of the jetties at South and Southwest Passes are in water depths of 20 to 30 ft.) Construction of early jetty projects, such as those at South and Southwest Passes, consisted of one to several layers of fascine mats, each layer ballasted with riprap stone, with additional stone added to obtain the desired crest elevation. (Significant portions of the Mississippi Passes jetties also were capped with concrete during original construction.) Fascine mats were used as late as 1939 at Southwest Pass, 1942 at Calcasieu Pass, and 1950 at Bayou Fontanelle. Construction of the most recent projects such as Gulf Outlet, Tiger Pass, and Baptiste Collette Bayou, has used shell materials as a bedding and core material, which then is covered with riprap or armor stone. These projects were constructed in two stages, the first being a wide base of shell and riprap stone as mentioned previously, and the second a rubble-mound section typical of jetty structures.

4. Settlement of structures due to soil consolidation and general subsidence of the Louisiana coastline (relative to existing water levels) have created the need to periodically raise several of the structures or extend them landward. For example, typical rates of settlement of 0.1 to 0.5 ft/yr have been observed on the Southwest Pass jetties. Numerous concrete caps

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* A table of factors for converting non-SI to SI (metric) units of measurement is presented on page 3.

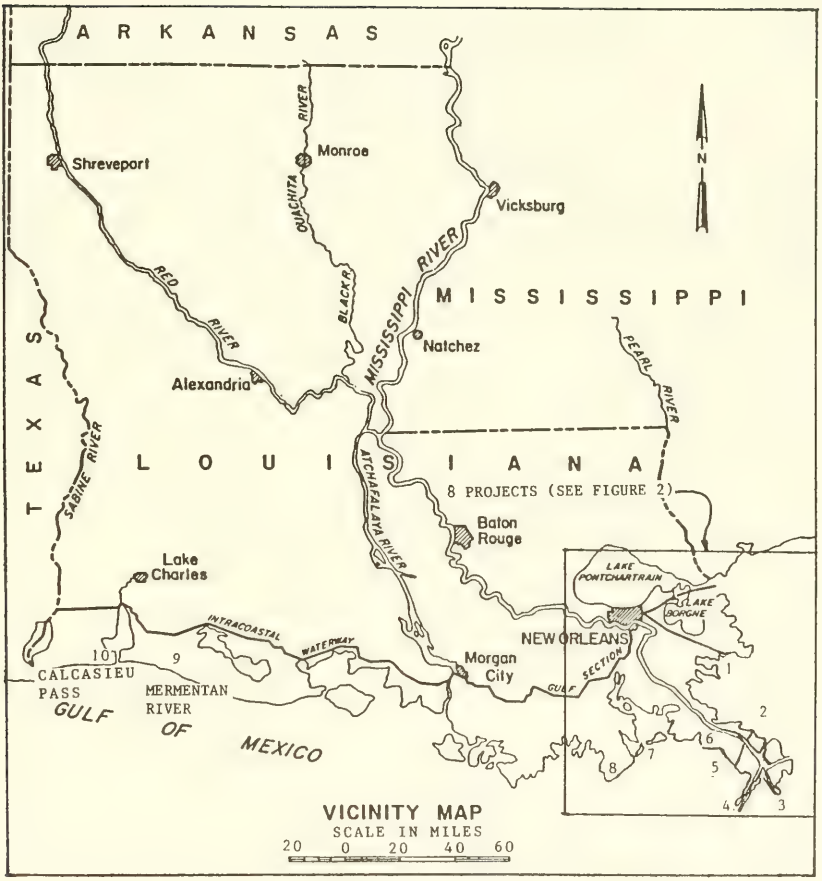

Figure 1. Location of gulf coast jetty projects under the jurisdiction of the Lower Mississippi Valley Division

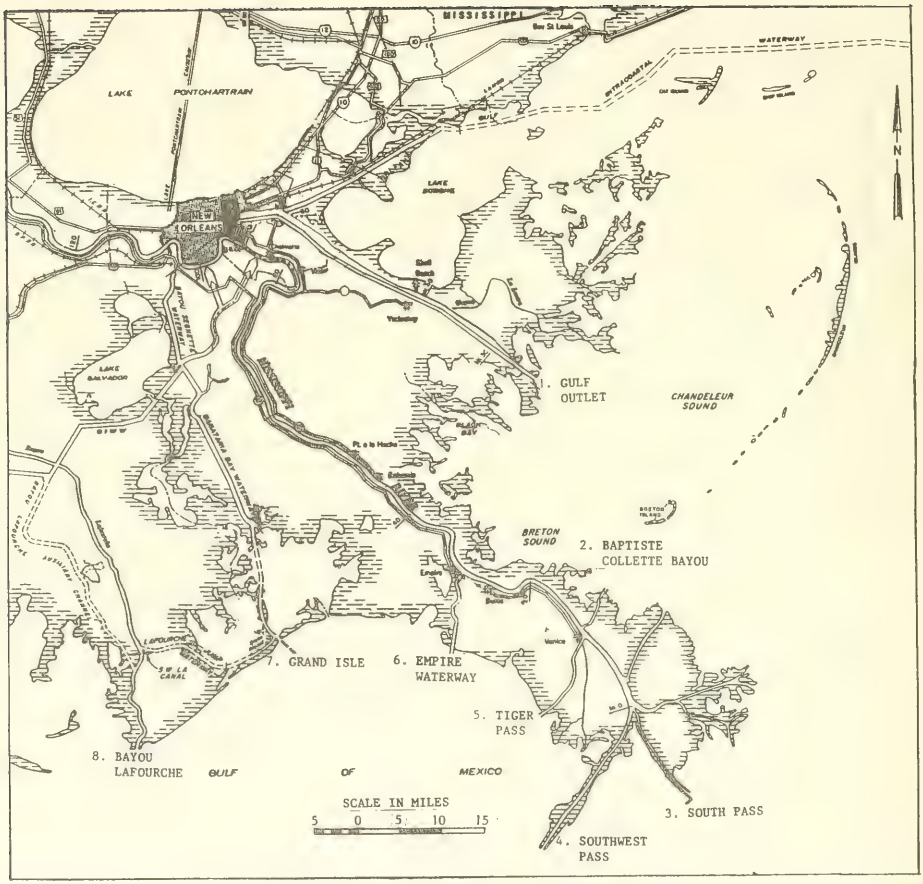

Figure 2. Location of jetty projects near the mouth of the Mississippi River

(prior to the 1960's) and large amounts of stone (during and after the 1960's) have been required to keep these jetties above mean high water (mhw). The only remaining jetty with a concrete cap is the South Pass east jetty. Landward extensions have been made to at least one jetty at the following projects: Bayou Fontanelle (part of the Empire to the Gulf of Mexico Waterway Projects), Grand Isle, Bayou LaFourche, and Calcasieu Pass. Plastic filter fabric has been tested on sections of the jetties at Tiger Pass and Baptiste Collette Bayou.

5. The structures are fairly low crested, being built or maintained at elevations from +3 to +6 ft mean low gulf (mlg). Typical design crown widths are from 4 to 14 ft. Design side slopes were 1V:1.5H on most of the older structures, while 1V:2H (or 1V:3H) usually has been used on the newer designs and repairs. Cover stone sizes typically have been 1 to 6 tons with a maximum of 10 tons used at the seaward ends of the South, Southwest, and Calcasieu Passes jetties. Several of the more recent repairs and designs have called for graded stone, typically 0 to 5,000 lb, placed by clamshell bucket. (The most recent repairs to Southwest Pass used 2- to 4-ton stone.) Shell or crushed bedding stone materials have been used as a core and bedding material, acting as a filter layer for the larger stone. Advantages of shell are its availability, lower cost than stone (per unit volume), and lower specific gravity.

6. Seven of the projects have had repairs since they were constructed originally (chronologically, the oldest projects). Southwest Pass jetties have the most extensive repair history. South Pass jetties have not required maintenance since 1970, and the channel has not been dredged since 1977. The majority of repairs were needed due to overall subsidence of structures. Steel sheet-pile jetties were constructed originally at Bayou LaFourche but were badly damaged within a year and had to be supplemented at the base with rubble stone. The projects at Grand Isle, Bayou LaFourche, and Mermentau River have had direct involvement by local or State interests in either their original construction or subsequent repairs.

7. General design of the structures has been concerned principally with their settlement. The structures are not designed for hurricane conditions, although they have been exposed to hurricane conditions in the Gulf of Mexico since construction. None of the structures have been model tested for stone slope stability. Hudson's equation and depth-limited wave heights are used

for selecting armor stone sizes. Case histories of the jetties for each project are included in Tables 1-10. Pertinent summary information on each project is in the following tabulation:

Location	Table	Project Type and No.*	Armor Type**	Length ft	Date of Origin	Improvement†
Gulf Outlet	1	J(2)	S	59,350	1960	R,D
Baptiste Collette Bayou	2	J(2)	S	16,000	1978	R
South Pass	3	J(2)	S,P,TC	13,640	1875	R,D
Southwest Pass	4	J(2)	S,P,B,A	31,650	1904	R,D
Tiger Pass	5	J(2)	S	7,400	1978	N
Bayou Fontanelle	6	J(2)	S	4,395	1950	R,D
Grand Isle	7	J	S	2,320	Unknown	R
Bayou LaFourche	8	J(2)	S,SSP	2,385	1939	R,D
Mermentau River	9	J(2)	S	Unknown	1971	N
Calcasieu Pass	10	J(2)	S	16,300	1893	R,D

* Indicates type and number of structure: j-jetty(j(2) indicates two jetties).
** Indicates armor type: S-stone, P-concrete, TC-timber crib, B-concrete blocks, A-asphalt, SSP-steel sheet pile.
† R-repair, D-modification, N-none.

Table 1

Mississippi River Gulf Outlet Jetties

Mississippi River Gulf Outlet, Louisiana

Date(s)	Construction and Rehabilitation History
1960	The River and Harbor Act of 29 March 1956 authorized construction of a 35-ft-deep by 500-ft-wide channel from New Orleans to the Gulf of Mexico as an alternative and necessary route in the event of emergency, war, or blockage of the Mississippi River. As part of the navigation improvements, jetties at the channel entrance also were authorized (Figures 2 and 3). Construction of the north jetty between 2264+00 and 2420+00 was completed at this time. The design section (Figure 4a) called for shell and riprap to be placed between retaining dikes composed of dredged fill. The dikes were placed from 25 to 35 ft on either side of the planned jetty center line and built up to elevations of +1 or +3 ft mean low water (mlw) on existing ground above or below -2 ft mlw, respectively. The shell material was placed to a center-line elevation of +1 ft mlw and 1V:7H side slopes. The 150- to 500-lb riprap was placed to an elevation of +3 ft mlw, a top width of 20 ft, and 1V:3H side slopes. Due to soil conditions, which consisted of predominantly fat clay with low shear strength, additional capping stone was to be added at a later date, thus allowing the existing soil mass to consolidate. As will be seen, this method was used throughout construction of the jetties. A total of 124,580 tons of riprap and 78,300 cu yd of shell was placed at a cost of $1,211,500.
1961	Capping stone was placed on the existing north jetty, and south jetty construction was completed between 2264+00 and 2420+00. On the north jetty, between 2262+50 and 2420+00, capping stone was placed to an elevation of +5 ft mlg, a crest width of 12 ft, and 1V:1.5H side slopes (Figure 4b). Stone size varied from 200 lb to 4 tons with 80 percent ranging from 2 to 4 tons. The larger pieces were placed on exposed surfaces. Existing jetty elevations, prior to capping, varied from +2 to +3 ft mlg. A total of 59,860 tons of stone was placed at a cost of $428,700. South jetty construction was identical to 1960 Phase I construction of the north jetty. The jetties are parallel and spaced 1,400 ft apart (Figure 3). A total of 115,190 tons of riprap and 90,360 cu yd of shell was placed at a cost of $846,300.
1962	The south jetty was capped between 2262+50 and 2420+00, with 4- to 6-ton stone. In addition, 500-lb to 2-ton stone was placed in a 2-ft-thick by 15-ft-wide layer on the channel side slope of the jetty adjacent to the capped section (Figure 4c). The cap design geometry was identical to the north jetty cap of 1961, with a +5 ft mlg crown elevation, 12-ft crown width, and 1V:1.5H side slopes. Prior to capping, typical elevations on the jetty (February 1962 survey) were from +1.5 to +3 ft mlg. A total of 107,500 tons of stone was placed at a cost of $717,100.

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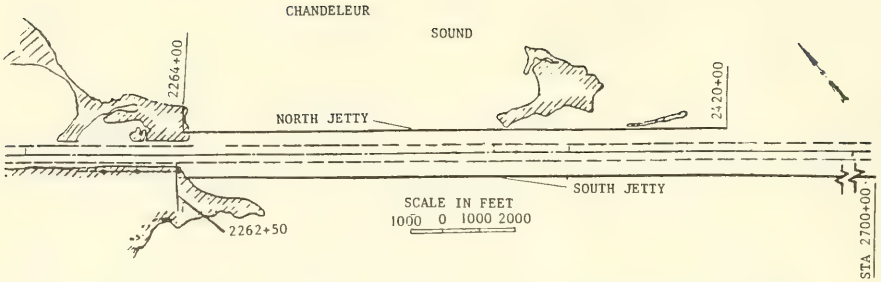
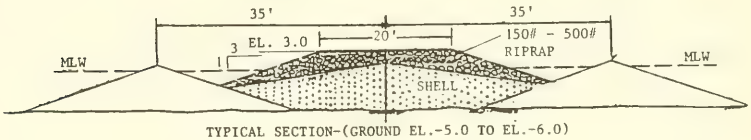
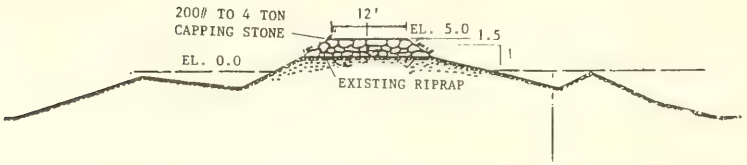


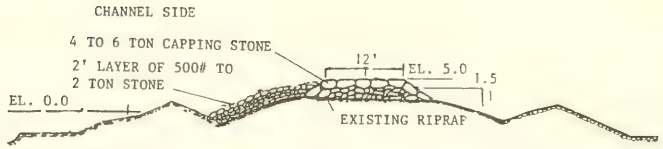
Figure 3. Plan view of Mississippi River Gulf outlet jetties



a. North jetty, 1960



b. North jetty capping, 1961



c. South jetty capping and channel slope stone, 1962

Figure 4. Typical design sections of Mississippi River Gulf outlet jetties

Table 1 (Continued)

Date(s)	Construction and Rehabilitation History
1963	Additional stone was placed along the channel side of the north jetty from 2264+00 to 2420+00. The 1,000-lb to 4-ton stone was placed to an elevation of +5 ft mlg, a top width extending 15 ft from the jetty center line, and a 1V:1.5H side slope. A total of 47,170 tons of stone was placed at a cost of $301,900.
1966	The south jetty was extended seaward from 2420+00 to 2525+00. The jetty construction was similar to the Phase I jetty construction during 1960-1961, with shell and riprap placed between retaining dikes composed of dredged fill. The dikes were placed 30 ft on either side of the jetty center line and built to an elevation of -1.5 ft mlg. The shell material was placed to -1 ft mlg and 1V:7H side slopes, followed by the 100- to 500-lb riprap placed to +1 ft mlg, a width of 20 ft, and 1V:3H side slopes. Total cost was $806,500 using 80,000 cu yd of shell and 106,200 tons of riprap.
1968	The south jetty was extended seaward from 2525+00 to 2649+00, using the same method of construction and design geometry stipulated during the 1966 extension. Total cost was $982,200 using 113,500 cu yd of shell and 114,000 tons of riprap.
1971	The south jetty was capped with armor stone from 2420+00 to 2650+00 (second phase construction) and extended seaward from 2649+00 to 2700+00 (first phase construction). The extended section was similar to the earlier south jetty extensions using a core (2650+00 to 2700+00) of shell and a cover layer of 100- to 500-lb riprap. Cost of the extension was $394,400 using 4,400 cu yd of shell and 51,000 tons of riprap. The capped section of the jetty consisted of 3- to 6-ton stone constructed to a crown elevation of +3 ft mlg, a 12-ft crown width, and 1V:1.5H side slopes. Additional stone, weighing 500 lb to 2 tons, was placed on the channel side of the jetty, adjacent to the capping stone. The stone was placed starting 9 ft from the jetty center line to a design elevation of +1 ft mlg and 1V:3H side slope. Prior to the capping, center line elevations varied from -1 to +1.5 ft mlg (March 1970 survey). Total cost of the improvements was $1,006,700 using 175,310 tons of stone.
1974-1975	Capping stone and channel side slope stone were placed on the south jetty from 2649+00 to 2700+00 (seaward end). This work was identical to the 1971 improvements, except that 2- to 4-ton stone was used to cap the jetty. Existing center-line elevations varied from -1 to +2 ft mlg (May 1974 survey). The total cost was $778,900 using 37,300 tons of stone.
1985	With the exception of the addition of channel side slope stone, the jetties have no repair history and are considered to be in good condition. The jetties were constructed in water depths less than

(Continued)

Table 1 (Concluded)

Date(s)	Construction and Rehabilitation History
1985 (cont.)	-7 ft mlg and are protected partially from the gulf wave climate by offshore barrier islands. A jetty survey was taken in 1981 about which we have no details, but information available on calculated stone quantities needed to bring the jetties up to grade indicates mean cross section elevations of about +2 and +1 ft mlg on the north and south jetties, respectively. Recently (early 1980's) consideration has been given to extending the deferred portions of the jetties to reduce maintenance dredging.

Table 2

Baptiste Collette Bayou Jetties

Mississippi River Outlets, Venice, Louisiana

Date(s)	Construction and Rehabilitation History
1978-1979	Two parallel jetties, spaced 520 ft apart, were constructed at the entrance to Baptiste Collette Bayou (Figure 5). With fairly impermeable jetties in place, significant reductions in dredging would be possible, thus reducing the overall cost of maintaining the Bayou channel. These jetties are similar to those constructed at Tiger Pass with the two waterways providing a shorter navigation route between east and west gulf waters. The east jetty is 9,000 ft long and extends 2,000 ft past the seaward end of the 7,000-ft-long west jetty. A 20- by 250-ft channel is maintained between the jetties. The east jetty (Figure 6a) was built in two geometric sections. The lower section had a crown elevation of +3 ft mlg, a crown width of 26 ft, and 1V:3H side slopes. The upper section had a +6 ft mlg crown elevation, a 4-ft crown width, and 1V:2H side slopes. The lower section was composed of shell material for the core and bedding layer (1-ft maximum thickness), followed by a 1.5-ft-thick layer of graded stone (500-lb maximum) placed on the side slopes only, and capped with a 2-ft-thick layer of graded stone (1,200-lb maximum) placed on the side slopes and crown. Graded stone (5,000-lb maximum) was placed in the upper section. The upper section was not constructed on a portion (approximately 950 ft) of the jetty. The west jetty (Figure 6b) had a crown elevation of from +3 to +4 ft mlg, a 26-ft crown width and 1V:3H side slopes. It was built up with a bedding layer (1-ft maximum thickness) of shell and filled out with graded (1,200-lb maximum) stone. Prior to construction, existing ground elevations were from +3 to -6 ft mlg. Both jetties were built on top of mostly soft clays and were expected to undergo large settlements (up to 4 ft). Plastic filter fabrics of varying tensile strengths were placed at four 500-ft-long test sections (2 sections per jetty), prior or subsequent to placing shell material. Two sections were at the seaward ends of the jetties and the remaining two started 4,000 ft from the landward ends. Settlement plates were placed at 80- to 90-ft intervals within test sections and at 500-ft intervals elsewhere. These were placed to monitor settlement and the effectiveness of the test sections. The total cost of construction was about $2,192,000 using 17,400 sq yd of fabric, 41,000 cu yd of shell, and 114,500 tons of graded stone.
1984	Repairs were made on the seaward end of the west jetty for a distance of 4,550 ft, and the entire east jetty was repaired (Figure 6c). (These were called repairs even though the original design called for two-phase construction.) Existing (1983 survey) center-line elevations on sections to be repaired were from +1 to +3 ft National Geodetic Vertical Datum (NGVD) on the west jetty and from +2 to +5 ft NGVD on the east jetty. (NGVD datum is about 0.5 ft above mlg datum).

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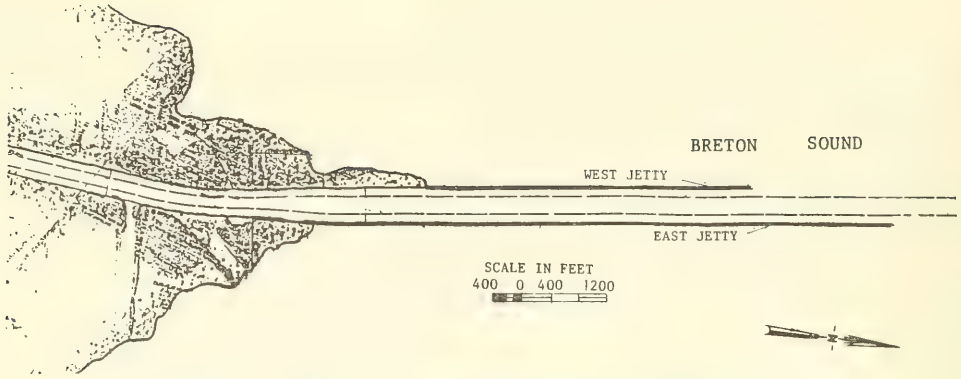
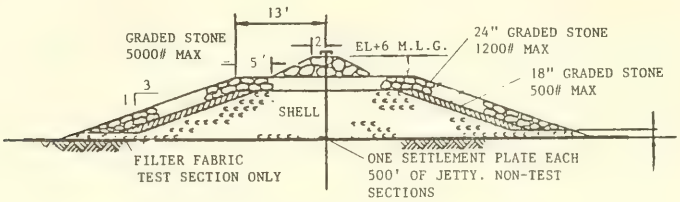
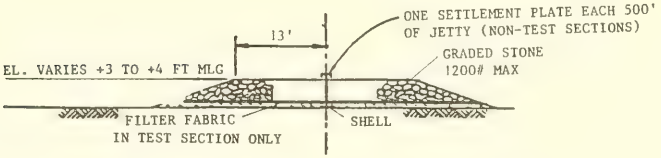


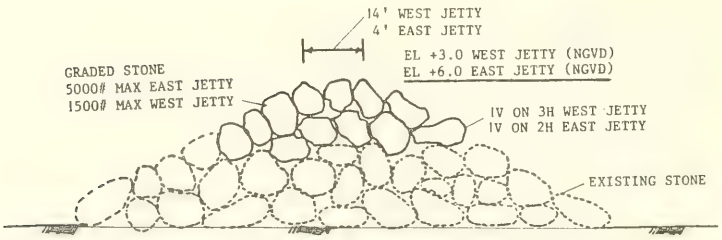
Figure 5. Plan view of Baptiste Collette Bayou jetties



a. East jetty, 1978



b. West jetty, 1978



c. Jetty repair, 1984

Figure 6. Typical design sections of Baptiste Coulette Bayou jetties

Table 2 (Concluded)

Date(s)	Construction and Rehabilitation History
1984 (cont.)	It appears that use of the plastic filter fabric in test sections to separate shelf materials has had little, if any, effect in retarding the rate of jetty settlement. The west jetty was brought up to +3 ft NGVD with a 14-ft crown width and 1V:3H side slopes. The east jetty was brought up to +6 ft NGVD with a 4-ft crown width and 1V:2H side slopes. Cost of the repairs was $512,000 with 22,100 tons of graded stone (5,000-lb maximum) placed on the east jetty and 11,500 tons of graded stone (1,500-lb maximum) placed on the west jetty.

Table 3

South Pass Jetties

South Pass, Louisiana

Date	Construction and Rehabilitation History
1875-1882	East and west jetties, 11,170 and 7,550 ft long, respectively, were constructed to provide protection and minimize maintenance dredging for a 26- by 200-ft channel from the Gulf of Mexico to the Mississippi River via South Pass (Figure 7). The jetties were built parallel, 1,000 ft apart curving slightly to the southwest, and terminated in water about 15 ft deep. The east jetty extended about 200 ft past the west jetty seaward end. The jetties were built on a base of fascine mattresses buttressed against rows of creosoted timber piles. The mats were sunk in place by accumulating sediment and addition of riprap stone. Multiple layers were placed in this fashion with narrower mats placed in successive layers up to about flood tide level. The mats were constructed of brush and timber of various sizes, bound together, from 30 to 60 ft wide, 75 to 100 ft long, and 2 to 2.5 ft thick. Timber cribs were placed at 100- to 200-ft intervals along the seaward several hundred feet of each jetty, providing additional protection and strength. The cribs consisted of timber piles laid in alternate horizontal courses, crossing each other at right angles. The piles in the floor courses were placed in contact with each other, and those of the upper courses were from 5 to 7 ft apart, thus forming compartments from 4 to 6 ft square. The cribwork was held together with metal connectors and sunk by filling the compartments with stone. The cribs were from 25 to 70 ft long, 15 to 20 ft wide, and 5 to 15 ft in height. (Depending on water depth, the tops were at about flood tide level.) Most of the cribs were placed on either side of the jetty mats (i.e. river or sea side). During 1881-1882 additional crib work was placed mostly on the east jetty landward of the existing cribs. Concrete cap blocks (cast in place) were placed along 5,430- and 2,750-ft-long sections at the seaward ends of the east and west jetties, respectively. The cap blocks were from 4 to 12 ft wide (widest at seaward ends), 20 to 50 ft long, 3 to 5 ft high, and placed atop a 1- to 2-ft-thick layer of riprap stone. In addition, the east jetty had a parapet wall, built partly of mortared stone and partly of concrete, placed on top of the cap blocks. The wall was from 3 to 4 ft wide and 2 to 4 ft high with original top elevations varying from 4.5 to 6.8 ft above flood tide level. The original top elevations of the remaining capped jetty sections were typically from 2 to 3 ft above flood tide level. Initial settlement of the concrete cap sections varied from 0.1 to 0.7 ft/yr with an average of 0.30 ft/yr for both jetties. Figure 8 is an 1880 cross section of the seaward end of the east jetty. During September 1882 approximately 3,000 ft of the east jetty cap was damaged during a passing hurricane.

(Continued)

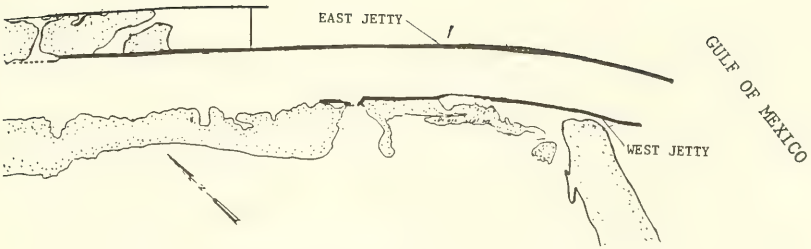


Figure 7. Plan view of South Pass jetties, 1951

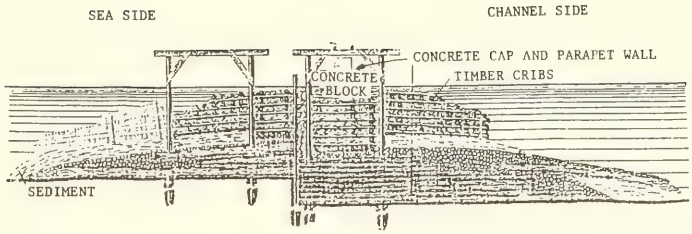


Figure 8. Seaward end of outer east jetty at South Pass, 1880

Table 3 (Continued)

Date(s)	Construction and Rehabilitation History
1883-1887	Inner jetties were constructed of horizontally placed willows (individual pieces were several inches in diameter) placed between vertical piles and maintained to an elevation 4 ft above flood tide level. More willows were added periodically as existing ones subsided. The inner east jetty was constructed about 200 ft inside the east jetty in two sections; a 1,940-ft section beginning near the landward terminus of the east jetty, and a 7,105-ft section extending to the seaward end of the east jetty. The 4,900-ft-long inner west jetty was constructed about 150 ft inside the west jetty (making the inner jetties 650 ft apart) terminating at its seaward end. Wing dams of similar design were built between the inner jetties and respective outer jetties creating rectangular compartments for trapping and accumulating sediments. During October 1886 a hurricane further damaged (removed) about 700 ft of the parapet wall near the seaward end of the east jetty. By 1887, accumulating sediments and settlements had buried the west jetty and landward 4,800 ft of the east jetty (although erosion of the deposited sediments east of the jetties was occurring).
1889-1901	In 1889, the east jetty concrete cap was repaired along those sections damaged during storms of 1882 and 1886. Approximately 3,710 ft of cap and 810 ft of parapet wall were rebuilt, and 320 ft of new parapet wall was constructed. Additional mats (as needed) and a 2-ft-thick layer of riprap stone were placed up to flood tide level prior to pouring new cap sections. Cap sections varied from 4 to 7 ft in width and 3 to 3-1/2 ft in height. During 1889-1893, continuous cribwork was placed beginning at the landward end of the concrete cap. It was extended landward several times, reaching a total length of 2,245 ft. This cribwork was at least partially required due to continuing erosion on the seaside of the jetty (at a rate of 200 ft/yr along the jetty). On several occasions, cribwork also was placed on the seaward ends (several hundred feet of each) of the inner jetties, providing wave and current protection along these exposed sections. The inner east jetty was extended landward several times (giving it a total length of 9,730 ft), employing the same construction method used during 1883-1887. Extensions were required due to continued landward recession east of the jetty and the need to limit sediment motions. In 1895, a storm destroyed the outer 100 ft of the inner west jetty. No subsequent repairs were made, leaving the effective length 4,800 ft. Additional wing dams were built and maintained together with those already built. In 1901, the contractors were reimbursed in the amount of $8,000,000 for maintaining the authorized channel dimensions for a cumulative period of 20 years (noncontinuous), which was the time period agreed upon in 1875.
1902-1920	The inner jetties and connecting wing dams now maintained by the Corps were repaired and brought up to grade as needed. The outer

(Continued)

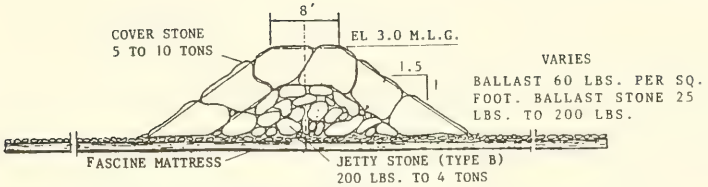
Table 3 (Continued)

Date(s)	Construction and Rehabilitation History
1902-1920 (cont.)	jetties were not (and will not be) maintained and had settled below the water surface, up to several feet in places. The majority of maintenance work consisted of placing willows and riprap stone ballast on the jetties (inner jetties are implied throughout the bulk of work). The average annual cost for maintaining the jetties during this period was $75,000. The maintained lengths of the east and west jetties were 11,170 and 4,710 ft, respectively.
1921	The outer 4,525-ft length of the east jetty was protected by construction of a heavy stone breakwater at a total cost of $198,000. Additional jetty maintenance was done at a cost of $62,000.
1922-1926	About 6,500 ft of the landward end of the east jetty was capped with concrete during 1922-1923. Sections of the east jetty were repaired using riprap stone capped with concrete during 1924-1926. This work and other minor repairs averaged $17,200 in annual costs.
1927-1929	A 5,200-ft-long longitudinal dike (willow brush and stone) was constructed 500 ft east of, and parallel to, an equal landward segment of the east jetty. The purpose of the dike and other features was to halt continued erosion at the landward end of the east jetty, create a permanent bank (formed by natural deposits) along the seaside of the jetty, and eliminate future maintenance. During 1928, other major work consisted of raising the outer 4,000 ft of east jetty up to grade with "large riprap stone" and repairing 3,000 ft of concrete cap by adding concrete and small riprap stone. Total maintenance cost during this period was $203,000.
1930-1931	The outer 4,300 ft of east jetty was capped with concrete to an elevation of +5 ft. The existing stone was reset prior to placing the 3-ft-wide cap. Additional repairs to the longitudinal dike brought the total cost for this period to $41,000.
1932-1938	No major work was undertaken. The annual cost for continued maintenance of the (inner) jetties and dike averaged $33,000.
1939-1949	In 1939 the seaward 5,440 ft of east jetty was repaired with 10,930 tons of stone and 4,420 cu yd of reinforced concrete cap at a total cost of $189,600. The cap was 8 ft wide with a top elevation of +7.5 ft mean gulf level (mgl). In 1940 the outer 4,300 ft of the 5,400-ft-long east dike was repaired with willows and stone, and the outer 2,700 ft of the west jetty was rebuilt with creosoted piles, brush, and stone. Total cost of the repairs was $76,700. In 1941 the seaward end of the east jetty was repaired with 1,140 tons of stone at a cost of $9,600. In 1949 the west jetty was repaired by construction of a treated timber piling curtain wall and stone dike at a total cost of $33,400.

(Continued)

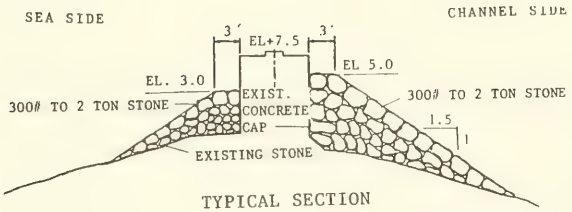
Date(s)	Construction and Rehabilitation History
1952	About 2,300 lin ft of east jetty was capped with concrete and 13,360 tons of stone placed at a total cost of $231,500. The cap section was placed immediately landward of the 1939 cap section and was 6 ft wide with a top elevation of +7.5 ft mlg. Stone was placed along the cap section and extended an additional 200 ft landward.
1955	Repairs to the west jetty consisted of a 1,125-ft-long rubble-mound jetty at the seaward end (Figure 9) built on the seaside of, and extending 350 ft seaward of, the existing bulkhead; and construction of 930 ft of stone dikes, 900 ft of fascine dikes, and 180 ft of sheet-pile weir, all on a 3,600-ft-long section landward of the rubble-mound section. Most of the rubble-mound structure was built on 40- to 70-ft-wide fascine mats ballasted with 25- to 200-lb stone (60 lb/per sq ft). A 300-ft section, at its landward end, was built on a 1-ft-thick layer of similar sized stone. The design cross section had a +3-ft-mlg crown elevation, crown widths of 5 ft (landward 300 ft) and 8 ft, and 1V:1.5H side slopes. The landward 300 ft was built up using 200- to 2,000-lb stone, and the seaward 300 ft had a cover layer of 5- to 10-ton stone. The jetty midsection and seaward core stone was 200 lb to 4 tons. Existing water depths varied from -2 to -20 ft mlg at the landward and seaward ends, respectively. The total cost of the jetty was $134,200 using 41,500 sq ft of mattress and 12,170 tons of stone. The steel sheet-pile weir was placed to an elevation of -3 ft mlg along a 100-ft section with an elevation of +5 ft mlg on adjacent 40-ft sections. A total of 1,040 tons of stone was placed along the weir length. A total of 11,270 and 850 tons of stone was placed on the stone and fascine dike sections, respectively. The total cost for the dikes and weir was $175,100.
1957	Repairs were made to 590 ft of the east jetty and to 110 ft of the west jetty outlet weir built in 1955. A total of 350 tons of stone was placed at several locations on the west jetty. The east jetty work, at the existing landward end (total jetty length, including present work, now 8,930 ft), consisted of 100 ft of rubble-mound weir, 390 ft of rubble-mound jetty on the existing structure, and 100 ft of new rubble-mound jetty. The weir design section had a 4-ft crown width at -2 ft mlg and 1V:1.5H and 1V:2H side slopes on the channel and seasides, respectively. The jetty design section had a 5-ft crown width at +5 ft mlg and 1V:1.5H side slopes. The stone size varied from 200 to 4,000 lb with the largest pieces placed in a 2.5-ft-thick cover layer. The sea side of the west jetty weir section had 5- to 75-lb riprap placed at a 1V:2H side slope beginning 10 ft from the steel sheet pile. This riprap was covered with a 1.5-ft-thick layer of 75- to 500-lb stone. Total cost for this work and repairs to Southwest Pass jetties was $499,400.
1966	The east jetty concrete cap was buttressed with stone (Figure 10) along 3,800- and 6,700-ft-long sections on the sea and channel sides,

(Continued)



TYPICAL SECTION

Figure 9. Seaward design section of the South Pass west jetty, 1955



TYPICAL SECTION

Figure 10. Stone buttressing of the concrete cap on the South Pass east jetty, 1966

Table 3 (Concluded)

Date(s)	Construction and Rehabilitation History
1966 (cont.)	respectively, both sections terminating at the seaward end. The 300-lb to 2-ton stone was placed to +3 and +5 ft mlg on the sea and channel sides, respectively, with a berm width of 3 ft and 1V:1.5H side slopes. A total of 38,300 tons of stone was placed at a cost of $264,000.
1970-1971	Two sections of the east jetty were repaired and a 100-ft-long jetty tie-in constructed. A 650-ft section of the concrete cap, located about 5,400 ft from the seaward end, was buttressed with stone. The design geometry was identical to that used in 1966 repairs (Figure 10). A 300-ft section and tie-in section, located 6,900 and 8,500 ft from the outer end, respectively, were built up to +7.5 ft mlg, with a 6-ft crown width and 1V:1.5H side slopes. The repairs were made with 300-lb to 2-ton stone, and a 1-ft-thick layer of shell was placed as bedding for the jetty tie-in. A total of 16,500 tons of stone and 500 cu yd of shell was used for an approximate total cost of $164,000.
1985	No new work has been done since 1971, and the project has been essentially inactive since 1978. All deep-draft traffic now uses Southwest Pass. Figure 11 is a 1977 photograph of the east jetty.

Figure 11. East jetty at South Pass, 1977

Table 4

Southwest Pass Jetties

Southwest Pass, Louisiana

Date	Construction and Rehabilitation History
1898-1908	In 1898 a board appointed to report on improvement of Southwest Pass recommended construction of two jetties. As a result of successful improvement of South Pass, commerce of the Port of New Orleans rapidly increased and a deeper channel was desired to meet growing demands of navigation. The act of 13 June 1902 approved construction of the Southwest Pass jetties. Jetty construction was started in 1904 and completed in 1908. The jetties were built up using tiers of fascine mattresses, each tier ballasted with stone and sunk. Mattress widths varied from 35 to 150 ft. The wider mats were placed on the bottom, and the number of tiers depended on the water depth. The top tier was placed at about mlw, a 1- to 3-ft-thick layer of riprap stone was placed to mhw, and a 12-ft-wide concrete cap was cast in place to a finished grade of +4.5 mhw. The east and west jetties were 21,000 and 15,000 ft long, respectively, and converged from a distance of 6,000 ft apart to a distance of 3,600 ft (Figure 12, existing layout). The authorized channel was to have a depth of 35 ft and a width of 1,000 ft. The total cost of construction was $2,630,000 using 1,086,000 sq yd of mattress, 328,300 tons of stone, and 44,500 cu yd of concrete.
1910-1912	The jetties were extended seaward -- the east jetty 2,900 ft and the west jetty 3,400 ft. The seaward ends were approximately 3,200 ft apart. Spur dikes were constructed in the lower 7 miles of the pass, including the jettied section, contracting the channel width to about 3,000 ft. Materials used in the jetty extensions were 286,000 sq ft of mattress and 121,000 tons of stone. An additional 9,800 tons of stone was used at the inner ends of the jetties. Total cost of the extensions and repairs was $903,000.
1914-1918	The jetties and extensions as originally built had settled to the point that considerable amounts of water overflowed the concrete and stone capping during high tide. To prevent this overflow, additional stone was placed on the outer sections, and concrete capping was placed along inner sections of the jetties. The outer 8,000- and 11,000-ft sections of the east and west jetties, respectively, had 75- to 2,000-lb marble stone (170 lb/ft^3) placed on the seaside of the existing concrete cap. The stone was placed from +1 to +2 ft mhw with 4- to 10-ft crown widths and natural side slopes. A total of 121,700 tons of stone was placed at a cost of $567,900. In 1916, approximately 9,180- and 6,150-ft-long sections of the east and west jetties, respectively, were capped with concrete. Except for 660 ft of the east jetty, the new cap sections were placed landward of ongoing stone repairs. The 3-ft-wide cap was placed on the existing cap to an elevation of +3 ft mhw. A total of 5,396 cu yd of concrete was used at a total cost of $55,600.

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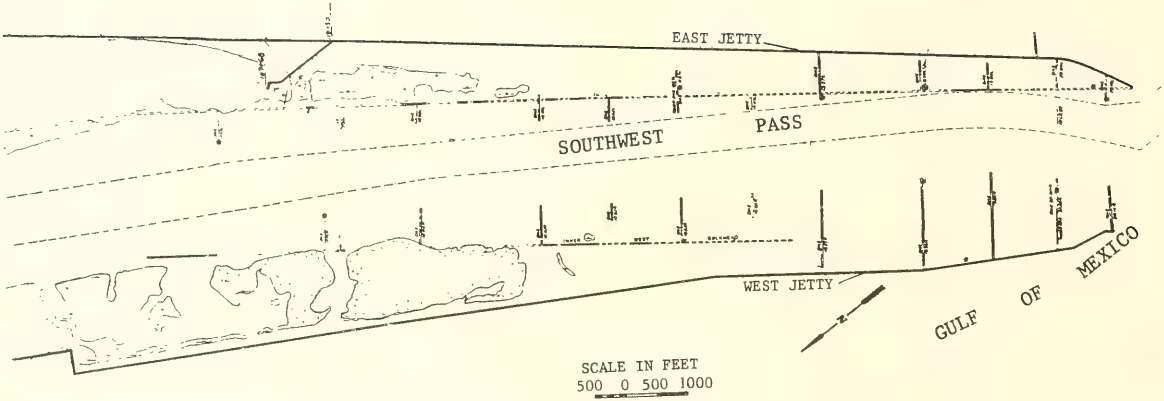

Figure 12. Plan view of the Southwest Pass jetties

Table 4 (Continued)

Date(s)	Construction and Rehabilitation History
1917-1923	Parallel bulkheads, consisting of wood sheet piles, brush- and rock-filled dikes, and fascine mats for scour protection, were constructed on the channel sides of the jetties. The bulkheads were spaced 2,400 ft apart. The east bulkhead (22,820 ft long) terminated at the seaward end of the east jetty, and the west bulkhead (16,120 ft long) terminated about 5,400 ft from the seaward end of the west jetty. Total cost for the bulkheads (construction, scour protection, and maintenance) was $2,584,000. In 1923, the existing spur dikes were extended and new dikes constructed, reducing the effective width of the pass to 1,750 ft. This contraction, combined with dredging, resulted in a 35-ft channel depth.
1921-1923	The east jetty was extended 1,100 ft to 250+00, and the west jetty was extended 850 ft to 190+50. The extensions and outer ends of the jetties (approximately 2,900 ft on the east and 4,900 ft on the west) were capped with concrete. Continued settlement and cumulative storm damages had lowered these sections so that at high tide considerable portions were submerged, allowing a significant (10 to 20 percent) amount of overflow. Extensions and capping costs were $664,000 and $614,000, respectively.
1924-1937	During this period the jetties were maintained by placing concrete capping and riprap stone (usually as a base for capping). As a result of continued jetty subsidence, capping was required to maintain flow between the jetties. During this period, most sections of both jetties were capped twice with roughly 70,000 lin ft of concrete placed over approximately 32,000 lin ft of active jetty. (Landward ends were essentially landlocked and required no additional work.) Concrete was placed to an elevation of +4.5 ft mhw (or +5.5 ft mgl) in lifts typically 3 to 4.5 ft high. Widths of the cap varied from about 6 ft at the seaward ends to 3 ft at the landward ends. The total cumulative cost for capping and stone was $1,170,000. In 1937, additional spur dikes were placed along the outer 10,000 ft of the jetties, reducing the effective channel width to about 1,400 ft. This addition was done in an effort to entirely eliminate maintenance dredging. Figure 13a is an east jetty cross section of cumulative work done up to 1937 in the general vicinity of 180+00.
1938-1939	The east jetty was repaired at the following locations: 163+00 to 164+60, 188+30 to 190+90, 197+10 to 198+10, and 206+00 to 210+00. Fascine mats (40 ft wide and sunk with 60 lb of stone per sq yd) were placed on each side of the jetty to prevent scour. The section was composed of 50- to 1,000-lb core stone and 3- to 7-ton cover stone. The design geometry consisted of a +6 ft mgl elevation, 15-ft-wide crown, and 1V:1.25 side slopes. A total of 24,300 tons of stone and 7,300 sq yd of mats was used. The seaward end of the east jetty was capped with concrete. A base of riprap stone was placed to +2 ft mgl, and the cap sections were 10 ft wide, 25 ft long, and placed to +4.7 ft mgl. The total cost of the repairs was $412,000.

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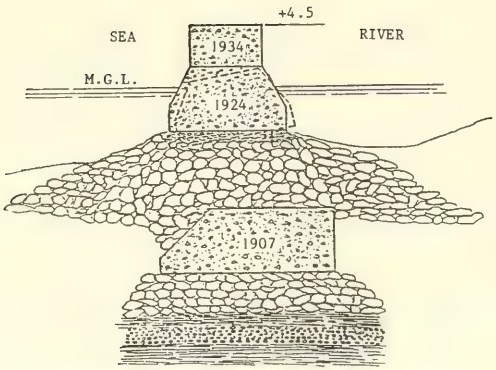
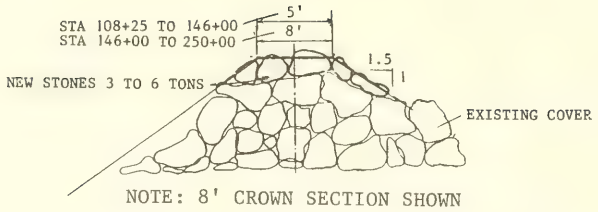


a. Cumulative work up to 1937 at 180+00



b. Typical repairs made during the 1970's

Figure 13. Southwest Pass east jetty cross sections

Table 4 (Continued)

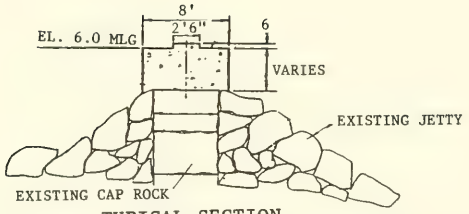
Date(s)	Construction and Rehabilitation History
1940-1949	The majority of jetties' maintenance consisted of placing stone on the east jetty in 1940, 1941, 1948, and 1949. A total of 241,515 tons of stone was placed on jetty sections totaling approximately 18,000 lin ft at a cumulative cost of $2,648,000. Other east jetty repairs were made in 1946 by placing about 6,960 tons of asphalt at a cost of $76,800. In 1942, the west jetty was capped with concrete blocks from 148+00 to 154+54 and intermittent concrete blocks (alternate block and gap sections were 20 to 25 ft long) from 169+75 to 174+85 at a cost of $22,300. (The capping was to have extended to the seaward end.) A September 1947 survey of the west jetty between 30+00 and 191+55 (seaward end) showed typical center-line elevations of +2 to +3 ft mlg over the landward half and +2 to -1 ft mlg over the seaward half (1942 capped sections were +3.5 to +4.5 ft mlg). A subsequent survey, taken during August 1949 between 148+00 and 191+55, showed a general settlement of 1 to 1.5 ft compared to the 1947 survey.
1950-1952	The west jetty was repaired between 35+00 and 191+55 by placing concrete blocks and armor stone to a design elevation of +6 ft mlg. In 1950, armor stone was placed from 174+85 to 191+55 with a design crown width of 6 ft and 1V:1.5H side slopes. Rectangular capstones, weighing 10 tons or more, were placed on top of the existing concrete cap. Rectangular (as opposed to irregularly shaped) capstone was used to create a relatively impervious jetty and to provide a suitable base for possible future concrete capping. Side slopes were built up on a layer of riprap stone, 25-lb to 4-ton core stone, and a cover layer of 5- to 10-ton stone (buttressing the capstones). Approximately 35,000 tons of stone were used, and the actual center line elevation varied between +5 and +6 ft mlg. Also completed in 1950 was the concrete capping between 154+54 and 174+85. The precast blocks were 5 ft wide, 3 to 7 ft high, and weighed 10 tons or more. The blocks were keyed (tongue and groove) on their ends and top, and once positioned were grouted with additional concrete. The capped section had typical center-line elevations of +6 to +6.5 ft mlg. During 1951-1952, the remaining section, 11,954 ft in length, was capped with concrete blocks. (A survey of this section, taken in December 1950, showed typical center-line elevations of +1 to +3 ft mlg.) The construction method was similar to the 1950 capping, using precast keyed blocks which were grouted in place. The blocks were specified to have a minimum length of 8 ft and widths of 3 and 5 ft on the landward and seaward sides of 142+45, respectively. The actual average length of the blocks was 15 ft, their weight varied from 10 to 16 tons, and their height varied from 3 to 7 ft. On 18 March 1952, prior to jetty completion, a "tidal" wave dislodged 180 blocks. At the time, all blocks were in place, but grouting had not been completed. A total length of 2,815 ft of cap blocks was reset and grouted at the following locations: 48+00 to 50+75, 79+60 to 80+60 to 95+60, 97+75 to 98+75, 101+45 to 102+80, 117+00 to

(Continued)

Table 4 (Continued)

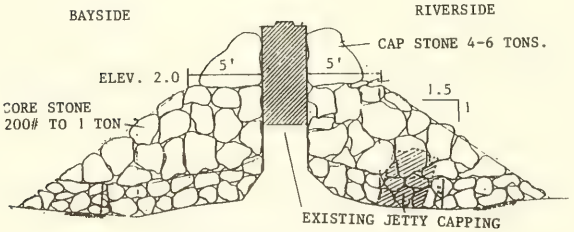
Date(s)	Construction and Rehabilitation History
1950-1952 (cont.)	122+20, and 126+30 to 142+15 (all these sections consisting of the narrower, 3-ft-wide blocks). The total cost for the concrete and stone capping was $889,000.
1954	The east jetty was repaired over a distance of 3,125 ft using approximately 18,900 tons of stone. Total cost of the repairs was $286,000. From surveys of the east jetty taken in April 1953 and July 1956, it appears that most of this work was carried out at the landward end between 127+00 and 163+00.
1956-1957	The east jetty was repaired with stone along its entire length from 127+00 to 250+00 (seaward end) and extended 800 ft at its landward end (to about 119+00). The seaward end of the west jetty was capped with concrete between 174+98 and 191+50 (Figure 14a, seaward section where rectangular cap stone was placed in 1951). The east jetty design cross section had an 8-ft crown width at +6 ft mlg and 1V:1.5H side slopes. Landward of 146+00 the design crown width was 5 ft. Two methods of stone placement were used: either additional cover stone (1 to 5 tons) was placed, or the existing cover stone (4 to 10 tons) was temporarily removed and additional 500- to 8,000-lb core stone was placed. The landward extension was to employ 200- to 4,000-lb stone, with the larger pieces placed as cover stone. Center-line surveys of the east jetty taken in April 1953 and July 1956 showed a general settlement of 1 to 2 ft and typical crest elevations of +4 to +5 ft mlg. The west jetty concrete cap was to be cast in place with individual blocks weighing not less than 15 tons. The blocks were to be keyed, be 8 ft in width, and have a +6 ft mlg crown elevation. Surveys of the west jetty taken in February 1953 and August 1956 showed a general settlement of 1 to 2 ft and typical crown elevations of +4 to +5 ft mlg, for the seaward repair section. Cost of the repairs and some work on the South Pass jetties (less than 20 percent of total) was $499,500.
1960	Repairs were made to the 3-ft-wide concrete cap section of the west jetty by resetting the blocks that had been dislodged during storm waves of 18 November 1957 and 16 February 1959. About 1,315 lin ft of cap was reset and buttressed with additional stone at sections 48+40 to 50+50 and 131+50 to 143+00. The design cross section (Figure 14b) used to supplement the concrete blocks consisted of a 2-ft-thick bedding layer of 25- to 200-lb stone, followed by 200- to 2,000-lb stone placed to +2 ft mlg (1V:1.5H side slopes and a 5-ft width on either side of the cap), and 4- to 6-ton stone was placed on either side of the cap. The principal purpose of buttessing was to provide a more stable cross section for the concrete blocks. The cap sections were buttressed with 16,400 tons of stone at a cost of $173,600.

(Continued)



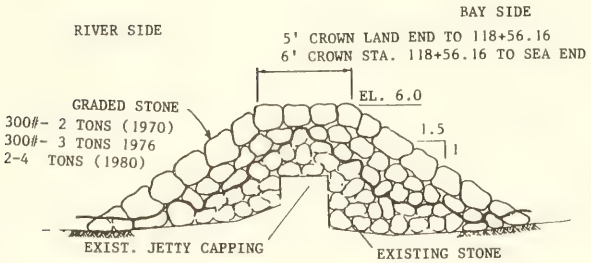
TYPICAL SECTION

a. Concrete cap placed at seaward end in 1956



THEORETICAL SECTION

b. Buttressing of concrete cap, 1960-1961



TYPICAL SECTION

c. Typical repairs made during 1970-1980

Figure 14. Southwest Pass west jetty cross sections

Table 4 (Continued)

Date(s)	Construction and Rehabilitation History
1961	The landward end of the west jetty was extended 1,550 ft and sections of its 3-ft-wide concrete cap were repaired. The landward extension was carried out between 19+50 and 36+00 (100-ft section was on existing jetty) using a 1.5-ft-thick by 16-ft-wide bedding layer of 25- to 200-lb stone, and overlayed with 200- to 2,000-lb stone (largest pieces on outer surface) to an elevation of +5 ft mlg, a 4-ft crown width, and 1V:1.5H side slopes. The repairs included resetting 750 lin ft of concrete blocks and buttressing these and adjacent blocks with stone at the following locations: 46+50 to 49+30, 65+00 to 67+00, and 126+00 to 131+50 (total of 1,030 lin ft). The cross section of buttressing stone was identical to that used during 1960 repairs (Figure 14b). Damage was caused by storm waves during Hurricane Ethel in September 1960. The cost of improvement was $160,800 with 6,600 and 12,900 tons of stone used on the extension and repair areas, respectively.
1962	New concrete capping was placed on top of the existing 5-ft-wide cap section of the west jetty between 143+00 and 174+89. The cap was cast in place, 5 ft wide, and the crest elevation was +6.5 ft mlg. Individual blocks were keyed and weighed a minimum of 15 tons but were not to exceed a length of 40 ft. In addition, stone was placed (to buttress the existing cap) to an elevation of +1 ft mlg, a crest width of 8 ft on each side of the cap, and 1V:1.5H side slopes. A 2-ft bedding layer of 25- to 200-lb stone was placed beneath 1- to 2-ton buttressing stone. Preexisting crest elevations, from a September 1961 survey, were from +2 to +4.5 ft mlg. The total cost of the improvements was $405,700 using 1,800 cu yd of concrete and 29,060 tons of stone.
1966	Several segments of the 3-ft-wide west jetty concrete cap section were repaired, similar to the 1960 and 1961 repairs (Figure 14b), by resetting and buttressing displaced blocks. About 4,330 lin ft of the cap blocks were reset, and buttressing of these and adjacent blocks totaled 4,565 lin ft at the following locations: 35+50 to 46+60, 50+20 to 55+00, 59+00 to 63+75, 77+00 to 82+00, 94+25 to 103+10, 115+65 to 125+65, 130+60 to 131+60, and 134+90 to 139+80. Also, additional 200- to 2,000-lb stone was placed along 480 lin ft of the jetty at the following sections: 34+15 to 34+75, 133+20 to 134+90, and 139+80 to 142+40. The design geometry for these sections was to have a crown elevation of +6 ft mlg, a 6-ft crown width, and 1V:1.5H side slopes. Altogether, 49,000 tons of stone was placed, and total cost of the repairs was $375,900.
1968-1969	The seaward half of the east jetty was repaired. The design section consisted of a +6 ft mlg crown elevation, an 8-ft crown width, and 1V:1.5H side slopes. The repairs required 47,500 tons of 500-lb to 4-ton core stone and resetting 5,440 tons of cover stone. The repair

(Continued)

1968-1969 (cont.)	involved removing existing 4- to 10-ton cover stone, adding core stone, and replacing the cover stone. The work was carried out on two sections, 190+00 to 194+00 and 200+40 to 247+70. A 1967 survey of the jetty showed average center-line elevations of +3.5 and +4.5 ft along the repair areas and remaining jetty, respectively. Total cost of the repairs was $498,800.
1970-1971	The landward end of the east jetty was repaired from 119+50 to 112+60 and extended 490 ft to 107+70. The west jetty was repaired from 142+40 to 124+90, from 63+00 to its landward end at 17+75, and extended 150 ft to 16+25. Stone size varied from 300 lb to 2 tons, with the largest pieces used as cover stone. The landward extensions had a 1-ft bedding layer of shell material placed prior to the stone. The design geometry (Figure 14c) had 1V:1.5H side slopes, a +6 ft mlg crown elevation, a 5-ft crown width on the landward sections, and a 6-ft crown width on the remaining west jetty section. Center-line elevations of the sections to be repaired averaged +4 ft mlg for the west jetty (1968 survey), +5 ft mlg for the east jetty (1970 survey), and the natural bottom of the east jetty extension varied from +6 to -5.5 ft mlg. The approximate cost of the repairs excluding South Pass east jetty which also was repaired under the same contract was $300,000 using 30,000 tons of stone and 1,000 cu yd of shell material.
1972	The east jetty was repaired from 140+00 to 167+00 using 3- to 6-ton armor stone. The design geometry (Figure 13b) specified a +6 ft mlg crown elevation, 5- and 8-ft crown widths shoreward and seaward of 146+00, respectively, and 1V:1.5H side slopes. An April survey (before repairs) of the jetty showed an average center-line elevation of +2.5 ft mlg within the repair area, and +3 ft mlg elsewhere. Cost of the repairs was $349,000 using 36,900 tons of stone.
1974	Two sections of the east jetty were repaired using the 1972 design geometry and stone size (Figure 13b). Crown widths were 5 ft, from 117+00 to 140+00, and 8 ft from 167+00 to 204+50. Cost of the repairs was $1,399,000 using 64,500 tons of stone. Figure 15 is a photograph taken in February showing three dredges operating between the jetties and a grounded vessel near the seaward end.
1975	The east jetty was repaired with 3- to 6-ton stone at locations 140+00 to 158+50 and 204+50 to 249+45 (seaward end). The design geometry (Figure 13b) had an elevation of +6 ft mlg, 1V:1.5H side slopes, and an 8-ft-wide crown (except from 140+00 to 146+00 which was 5 ft wide). After repairs were completed, it was noted that additional stone between 204+50 and 249+45 would be needed to stabilize the gulf side slope because some of the new slope stones were removed during periods of heavy wave action. The total cost was $2,306,800, and 103,660 tons of stone were required.

(Continued)

Figure 15. Southwest Pass jetties, 1974

Table 4 (Continued)

Date(s)	Construction and Rehabilitation History
1976	The west jetty was repaired with stone at 63+00 to 124+90 and 142+40 to 191+80 (seaward end). The stone size ranged from 300 lb to 3 tons, with the largest pieces used as cover stone. The design cross section (Figure 14c) had a crown elevation of +6 ft mlg, crown widths of 5 and 6 ft (landward and seaward of 118+50, respectively), and 1V:1.5H side slopes. It appears that a survey benchmark error occurred and that the actual crown elevation could have been +7.4 ft mlg. An October 1975 survey showed an average center-line elevation of +2 ft mlg on the sections to be repaired and from +4 to +5 ft mlg on the remaining sections. The total cost of the repair work was $3,517,200 using 186,760 tons of stone.
1978	Three sections of the east jetty were repaired (Figure 13b) at the following locations: 108+25 to 150+00, 165+50 to 206+50, and 244+50 to 250+00. Graded stone (less than 5,000 lb in size) was placed to an elevation of +6 ft mlg with crown widths of 5 and 8 ft landward and seaward of 146+00, respectively, and 1V:1.5H side slopes. Pre-existing center-line elevations, from a May survey, were +3 to +6 ft mlg along the repair sections, and +6 to +7 ft mlg elsewhere. A total of 48,000 tons of stone was placed at a total cost of $760,000.
1980	Two sections of the west jetty were repaired (Figure 14c) with armor stone (possibly 2- to 4-ton size). The crown elevation was +6 ft mlg, and the side slopes were 1V:1.5H. The landward section, from 20+00 to 63+00, had a 5-ft crown width; and the seaward section, from 123+00 to 142+40, had a 6-ft crown width. Prior to repairs, an April 1979 survey showed center-line elevations averaging +4 ft mlg within the repair areas and from +4 to +7 ft mlg over the remainder of the jetty. Total cost of the repair work was $1,104,300 using approximately 43,000 tons of stone.
1981-1982	The landward and seaward ends of the east jetty were repaired (Figure 13b) with armor stone (possibly 2 to 4 ton size) at the following locations: 108+25 (landward end) to 150+30, 155+70 to 165+40, and 217+55 to 250+00 (seaward end). The design geometry had a +6 ft mlg crown elevation, 1V:1.5H slide slopes, and crown widths of 5 ft (landward of 146+00) and 8 ft (seaward of 146+00). Prior to repairs, center-line elevations (September 1980 survey) varied from +4 to +6 ft mlg along the landward sections, from -2 to +6 ft mlg on the seaward section, and from +5 to +7.5 ft mlg elsewhere. Total cost of the repairs was $820,000 using 37,500 tons of stone.
1984	Repairs were made to both jetties using 2- to 4-ton stone. The east jetty was repaired at three sections 170+00 to 178+50, 192+50 to 209+50, and 242+50 to 250+00 (seaward end), and the west jetty was repaired at 3 sections 103+00 to 124+00, 160+00 to 166+50, and 176+00 to 191+50 (seaward end). Stone was placed to +6 ft NGVD, 1V:1.5H

(Continued)

Table 4 (Concluded)

Date(s)	Construction and Rehabilitation History
1984 (cont.)	side slopes, and crown widths of 8 and 6 ft on the east and west jetties, respectively. Preexisting center-line elevations were typically from +4 to +6 ft NGVD within the repair areas and from +6 to +9 ft NGVD on the remaining sections. Total cost of the repairs was $715,900 using 32,380 tons of stone.
1986	The lengths of the east and west jetties, as presently maintained, are 14,200 and 17,450 ft, respectively. Future plans specify rebuilding the old inner bulkheads with riprap stone.

Table 5

Tiger Pass Jetties

Mississippi River Outlets, Venice, Louisiana

Date(s)	Construction and Rehabilitation History
1978-1979	Two parallel rubble-mound jetties were built at the entrance to Tiger Pass (Figure 16) in order to reduce the amount of maintenance dredging required for safe navigation. These jetties were part of navigation improvements which included similar jetties at the entrance to Baptiste Collette Bayou (Figure 2), also built during this time. These waterways provide a shorter navigational route between east and west gulf waters and are used primarily by smaller vessels. The north and south jetties were 4,700 and 2,700 ft long, respectively, and spaced 540 ft apart with a 17- by 250-ft channel between them. The north jetty extended 2,000 ft past the seaward end of the south jetty. The design cross section (Figure 16) had a crest elevation of +3 ft mlg, a crest width of 26 ft, and 1V:3H side slopes. Shell material was used as core and bedding material (1-ft minimum thickness). A 1-ft-thick layer of graded "c" stone (500-lb maximum) was placed on the core side slopes followed by a 2-ft-thick layer of graded stone (1,200-lb maximum) placed on the side slopes and crown. Plastic filter fabric was placed at four test sections (two per jetty) prior to placing the shell and stone. Two 500-ft sections were at the seaward ends of the jetties and the remaining two (500 and 1,000 ft long on the north and south jetties, respectively) begin 1,000 ft from the landward ends and extend seaward. Test sections were subdivided into 250-ft reaches, in which different tensile strength fabric was placed or the design section was modified ("c" stone omitted on two reaches). Settlement plates were placed at 80- to 90-ft intervals within the test sections and 500-ft intervals elsewhere. These were placed to monitor settlement and effectiveness of the test sections. The jetties were built on top of mostly soft clays and were expected to settle 2 ft. For this reason, the south jetty, which eventually was to be built up to +6 ft mlg with graded stone (5,000-lb maximum) was to be constructed in two phases, with the portion above +3 ft mlg to be built at a later date. Prior to jetty construction, existing elevations were from +3 to -6 ft mlg. The total construction cost was $2,085,000 using 31,500 sq yd of plastic filter fabric, 76,400 cu yd of shell material, and 105,200 tons of graded stone. A late 1979 inspection indicated that the jetties had what appeared to be large amounts of differential settlement and already constituted a maintenance problem.
1984-1985	Repairs were made to both jetties. The south jetty was raised with graded stone (5,000-lb maximum) to an elevation of +6 ft NGVD, a 4-ft crown width, and 1V:2H side slopes. The north jetty was repaired with graded stone (1,500-lb maximum) to an elevation of +3 ft NGVD, a 14-ft crown width, and 1V:3H side slopes (NGVD datum approximately 0.5 ft above mlg datum). Raising the south jetty was the second

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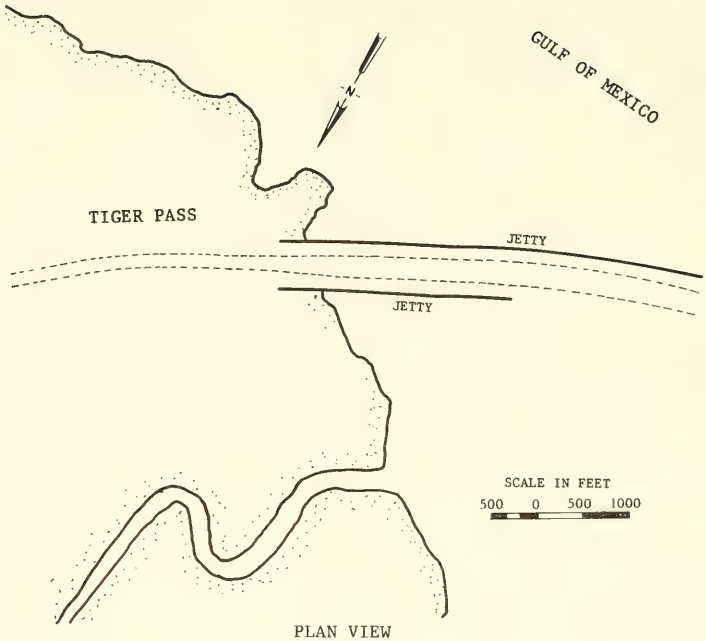
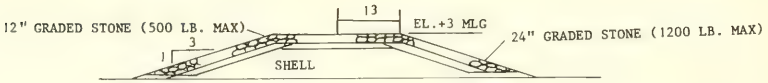
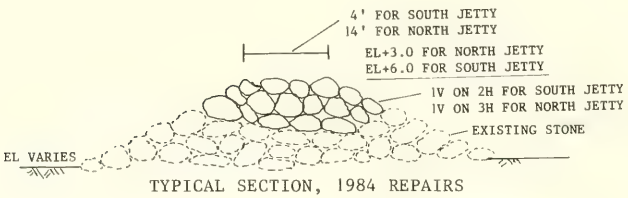


PLAN VIEW



TYPICAL SECTION, 1978-79 CONSTRUCTION


4' FOR SOUTH JETTY
14' FOR NORTH JETTY
EL+3.0 FOR NORTH JETTY
EL+6.0 FOR SOUTH JETTY
1V ON 2H FOR SOUTH JETTY
1V ON 3H FOR NORTH JETTY
EXISTING STONE
EL VARIES

TYPICAL SECTION, 1984 REPAIRS

Figure 16. Plan view of Tiger Pass jetties and typical cross sections

Table 5 (Concluded)

Date(s)	Construction and Rehabilitation History
1984-1985 (cont.)	phase of planned construction, required due to the existing foundation conditions (soft clays) and potential for failure if it were built in one phase. For the same reason the structures were not overbuilt. Total settlement of the south jetty is expected to be 4 ft. Future maintenance work such as additional stone placement will be required to maintain the jetties' design elevations. Prior to repairs, center-line elevations (1983 survey) were typically +1 to -2 ft NGVD on the south jetty and 0- to -1 ft NGVD on the north jetty. Use of plastic plastic filter fabric appears to have had little, if any, effect on the rate of jetty settlement. The estimated cost of the repairs was $1,340,000 with 27,500 and 45,000 tons of stone to be placed on the north and south jetties, respectively.

Table 6

Bayou Fontanelle Jetties

Empire, Louisiana

Date(s)	Construction and Rehabilitation History
1950	Two rubble-mound jetties were constructed (Figure 17, existing layout) in conjunction with a 9- by 80-ft navigable channel (between Empire, Louisiana, and the Gulf of Mexico). The jetties were constructed out to the -6 ft mlg contour (original lengths unknown) and spaced 425 ft apart. The jetties were of rubble-mound construction placed on fascine mattresses. The design geometry (Figure 17) had a +6-ft mlg crown elevation, 10-ft crown width, and 1V:1.25H side slopes.
1970	The seaward ends of the jetties were repaired, the landward end of the west jetty was repaired and extended 420 ft, a 475-ft-long groin was constructed 300 ft west of the west jetty, and a 325-ft-long tie dike was built, connecting the groin to the west jetty (Figure 17, repair history prior to 1970 not known). Prior to repairs, the east and west jetties were 1,800 and 1,850 ft long, respectively, and typical center-line elevations (1970 surveys) varied from +3 to +6 ft mlg on the east jetty, and from +4 to +6 ft mlg on the west jetty. The landward end of the west jetty had been flanked and was about 300 ft from the existing shoreline with intervening water depths to -7.5 ft mlg. The jetty sections were to be built to an elevation of +6 ft mlg, a 10-ft crown width, and 1V:1.5H side slopes. Sections of the seaward ends of the east and west jetties, 960 and 190 ft long, respectively, and the landward end of the west jetty, 400 ft long, were repaired with 1- to 6-ton stone. The groin, dike, and west jetty extension were constructed with 300-lb to 2-ton stone and a shell blanket, to be placed to -2.5 ft mlg or a minimum thickness of 1 ft. A shell core placed to -1 ft mlg, a top width of 20 ft, and 1V:4H side slopes was used on the west jetty extension where the existing grade was less than -3.5 ft mlg. The "as built" stone side slopes of this section were approximately 1V:2H. The shallower side slopes provided a cover layer of stone along the exposed toes of the shell core. Prior to this modification, scour and undermining were removing the shell material. The groin and dike design elevations were +5 and +4 ft mlg, respectively, with 6-ft crown width and 1V:1.5H side slopes. The cost for placing an estimated 16,900 tons of stone and 7,400 cu yd of shell was $196,000.
1978	The west jetty was repaired along 75- and 1,375-ft sections at the landward and seaward ends, respectively; its landward end was extended 325 ft; and the tie dike and groin were repaired. A graded stone, with a maximum stone size of 5,000 lb, was placed on the structures using the 1970 design geometries. (The jetty extension had a 1-ft-thick shell bedding layer.) The preexisting center-line elevations (April survey) on the west jetty averaged +2 and

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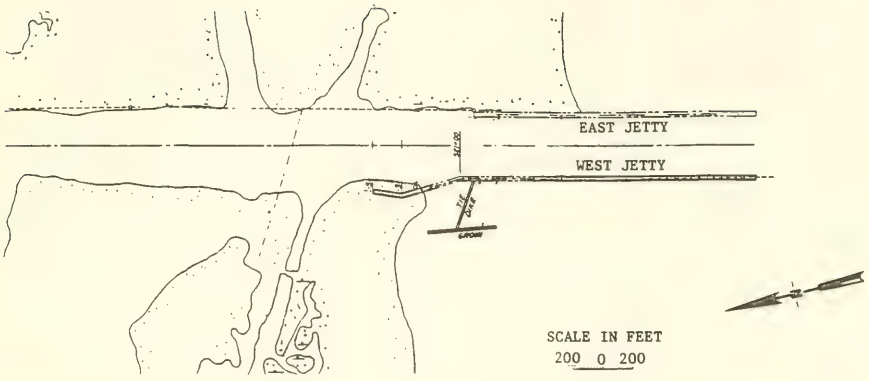
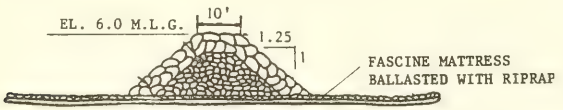
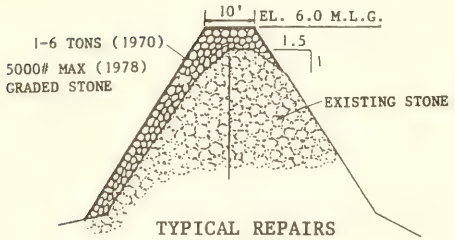




ORIGINAL JETTY DESIGN, 1950



TYPICAL REPAIRS
1970, 1978

NOT TO SCALE

Figure 17. Plan view of Bayou Fontanelle jetties and typical cross sections

Table 6 (Concluded)

Date(s)	Construction and Rehabilitation History
1978 (cont.)	+4.5 ft mlg on the landward and seaward sections, respectively, and from +6 to +8 ft mlg elsewhere. The tie dike and groin elevations varied from +2.5 to +4 ft mlg and from +2.5 to +6 ft mlg, respectively. The landward end of the groin had been flanked but was not extended at this time. A total of 440 cu yd of shell and 4,650 tons of stone was used at a total cost of $137,500.
1985	Although the exact state of the jetties is not known, they are considered to be in good condition.
1987	The landward end of the west jetty has been outflanked by bankline erosion. Plans for a landward extension have been developed by the district.

Table 7

Grand Isle Jetty

Jefferson Parish, Louisiana

Date(s)	Construction and Rehabilitation History
1958 1959	The jetty was constructed by the Louisiana Department of Public Works approximately 1,000 ft west of the eastern end of Grand Isle. The jetty was approximately 935 ft long. It was founded on a timber mattress and had a 6-ft crown width with 1V on 1.5H side slopes.
1964	The jetty was extended 1,400 ft by the State of Louisiana with essentially the same cross section used for initial construction.
1966	The jetty at the east end of Grand Isle (west side of Barataria Pass) was repaired with shell and stone (Figure 18). Existing center-line elevations (October 1965 survey) varied from -8.5 to +3 ft mean sea level (msl). The repairs were carried out along 2,320 ft of the jetty from 2+60 to 25+80 (seaward end). The landward end of the repair section was approximately 200 ft from the existing shoreline. The design section (Figure 18) called for a +3 ft msl crown elevation (+4 ft msl on landward 340 ft), a 6-ft crown width, and 1V:1.5H side slopes. A bedding layer of shell was placed at two sections, 12+90 to 14+20 and 15+80 to 16+60. A total of 7,500 tons of 500-lb to 4-ton stone and 770 cu yd of shell was placed at a total cost of $83,500. After the jetty repairs, the State of Louisiana placed about 200 lin ft of sand dike between the existing shoreline and the landward end of the jetty. The dike was to have a crest elevation of +8 ft, and additional shell and 25- to 1,000-lb stone were to be used at the jetty junction. The cost for the dike was to be reimbursed by the Federal government (no details).
1972	A jetty was constructed at the west end of Grand Isle.
1985	Additional information on the jetty was not found, and its present condition is unknown.

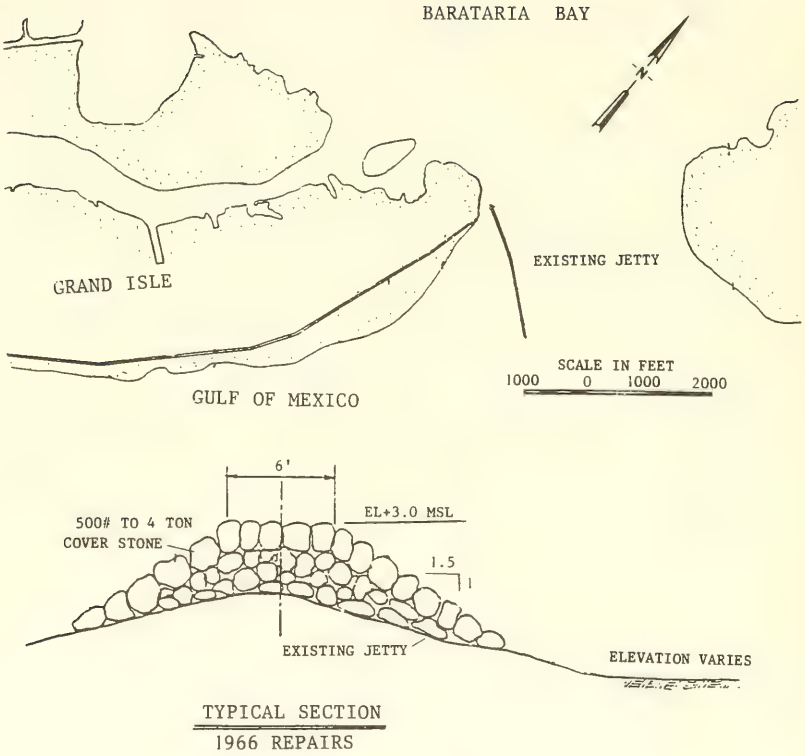


Figure 18. Plan view of Grand Isle jetty and typical 1966 repair section

Table 8

Bayou LaFourche Jetties

Bayou LaFourche, Louisiana

Date(s)	Construction and Rehabilitation History
1939	Two steel sheet-pile jetties were constructed at Belle Pass (Figure 19) providing protection for an authorized 6- by 60-ft channel. The jetties were 690 and 570 ft long on the east and west sides, respectively, and extended out to about the -6 ft mlg contour. The seaward 350-ft sections of the jetties were parallel and spaced 190 ft apart, and landward ends flared out at 45 deg angles. The tops of the sheet piles were driven to 0 ft mlg and bracketed by a double row of creosoted timber piles placed to a top elevation of +5.3 ft mlg. A 3-ft-thick layer of riprap was placed at the seaward end of each jetty, extending a distance of 50 ft.
1940-1941	Storm action in 1940 badly damaged the jetties, and they subsequently were reinforced at their bases with rubble stone. In 1941 the landward ends of the jetties were repaired and extended using 2,090 tons of stone.
1948-1954	During this period additional stone was placed on the jetties, landward extensions were made, and a rubble-mound groin was constructed about 250 ft east of the east jetty (Figure 19). The jetties were flanked during a 1947 hurricane, necessitating repairs and landward extensions in 1948. A rubble-mound section was placed along portions of the sheet-pile jetty. In 1952 further maintenance work was done on the rubble-mound sections which were brought up to grade. Additional work was done in 1953, including landward extension of the jetties (making the total length of each about 1,000 ft) and construction of a 120-ft-long east groin. In 1954 the groin was extended seaward 120 ft, and additional work was done to bring the remainder of the jetties up to grade. By this time, stone placed on the seaward sides of the jetties had been brought up to +6 ft mlg with a 1V:1.5H side slope (same elevation and side slopes used on landward extensions). The landward jetty extensions and groin were required due to the continued recession of the shoreline, averaging about 15 ft/yr. The steel sheetpiling was still in place but was no longer considered effective. Cover stone sizes ranged up to a maximum of 6 tons.
1958	About 570 ft of the seaward end of the west jetty (the 1939 section) was moved 115 ft westward because the original width was inadequate for increased use of the waterway (Figure 19). This work was carried out by the State of Louisiana Department of Public Works.
1960	The jetties and groin were repaired with additional 500-lb to 4-ton stone. Prior to repair, center-line elevations (January survey) were from -3 to +7 ft mlg on the west jetty, from +3.5 to +6 ft mlg on

(Continued)

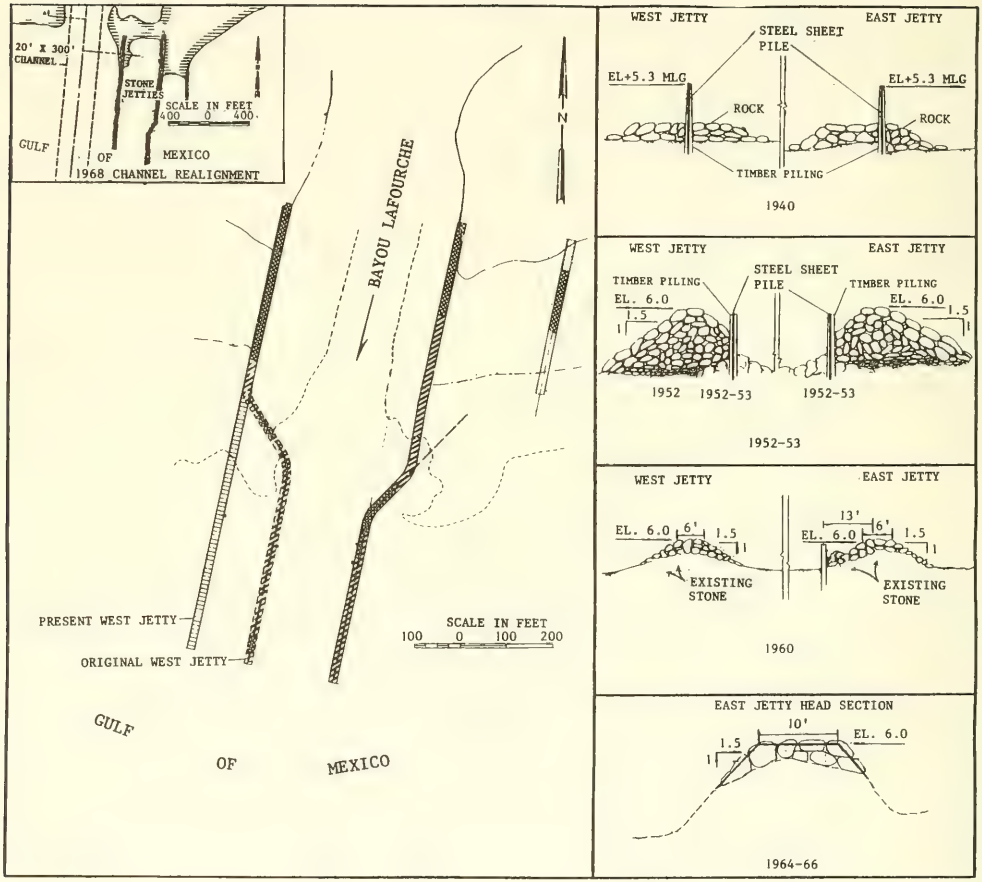


Figure 19. Plan views of Bayou Laforche jetties and typical cross sections

Table 8 (Continued)

Date(s)	Construction and Rehabilitation History
1960 (cont.)	the east jetty, and from 0- to +5 ft mlg on the groin. Soil subsidence was considered to be the major cause of jetty deterioration. Seaward sections of the east and west jetties, 700 and 800 ft long, respectively, were brought up to +6 ft mlg with a 6-ft top width and 1V:1.5H side slopes. The 345-ft-long groin was repaired to an elevation of +5 ft mlg, a 5-ft top width, and 1V:1.5H side slopes. Stone size was determined from Hudson's formula for a 9-ft depth-limited wave height. (The design called for the larger stones to be placed on the outermost surface.) The $56,000 cost of repairs included sweeping (removing exposed rock, piles, etc.) a 150-ft-wide section along the channel side of the west jetty and placing about 4,000 tons of stone.
1964	Repairs were made to the groin and sections of the east jetty. The landward ends were extended, making the east jetty and groin 1,250 and 630 ft long, respectively. These extensions were needed due to continued recession of the shoreline, which resulted in flanking of both structures. The groin was brought up to +5 ft mlg with a 6-ft top width and 1V:1.5H side slopes, using 1- to 6-ton stone on the seaward section and 200- to 2,000-lb stone on the 250-ft landward extension. (A 1-ft-thick bedding layer was placed also.) The east jetty sections were brought up to +6 ft with 1V:1.5H side slopes using 1- to 6-ton stone. The top widths were 6 ft on the 275-ft landward (including extension) and 125-ft middle sections, and 10 ft on the 200-ft seaward end section. Prior to repairs, the center-line elevations (September 1963 survey) were from -2 to +3.5 ft mlg on the groin, from +3 to +7 ft mlg on the east jetty, and from +5 to +9 ft on the west jetty. The total cost of placing 8,240 tons of stone and 600 lin ft of sand fence was $48,900.
1966	Repairs were made to the groin and east jetty, their landward ends were extended 100 and 135 ft, respectively, and a 290-ft-long rubble-mound dike was constructed along the shoreline, connecting the two structures. The existing center-line elevations (December 1965 survey) were from +1 to +5 ft mlg on the groin and from +1 to +7 ft mlg on the east jetty. The design geometries were identical to those used in 1964. A 1-ft-thick blanket of shell was placed along 200-ft sections at the landward ends of the structures and along the dike. These sections were completed using 500- to 4,000-lb stone, and the remaining repairs used 1- to 6-ton stone. The dike was built up to +4 ft mlg with a 10-ft crest width and 1V:1.5H side slopes. The crest width was 10 ft along a 250-ft section at the seaward end of the east jetty. The cost of the repairs was $43,500 using 4,280 tons of stone and 725 cu yd of shell.
1968	The Greater LaFourche Port Commission dredged a new 20- by 300-ft channel about 300 ft west of the existing channel which was closed after completion of the new channel (Figure 19).

(Continued)

Table 8 (Concluded)

Date(s)	Construction and Rehabilitation History
1985	Apparently, local interests have constructed a new jetty on the west side of the channel. The date is unknown, and the stone used may have come from one of the old jetties. The present condition of the jetties is unknown.

Table 9

Mermentau River Jetties

Mermentau River, Louisiana

Date(s)	Construction and Rehabilitation History
1971-1976	The 4.6-mile-long Mermentau River-Gulf of Mexico navigation channel was constructed in 1971 by the East Cameron Port, Harbor, and Terminal District of Cameron Parish. Two jetties were constructed providing protection for the 15- by 200-ft gulf entrance channel (Figure 20). Federal assumption of maintenance of the channel was authorized in 1976.
1985	The jetties have not been repaired since their construction. Details of the jetties' construction were unavailable, and their present condition is unknown.
1987	The bankline has eroded away from both jetties, and plans and specifications have been developed.

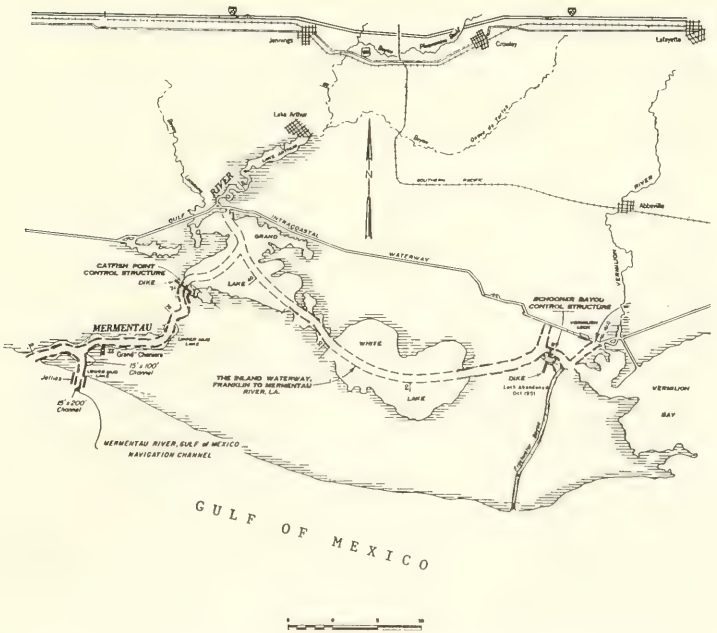


Figure 20. General location of Mermentau River jetties

Table 10

Calcasieu Pass Jetties

Calcasieu River and Pass, Louisiana

Date(s)	Construction and Rehabilitation History
1893-1905	Two jetties were constructed at Calcasieu Pass to secure a 12- by 200-ft channel (Figure 21). The method of construction was similar to that for the Sabine Pass Jetties which consisted of stone placed on a foundation mattress of brush. The east jetty was built during 1893-1897 to a length of 7,850 ft, and the west jetty was built during 1896-1900 to a length of 3,200 ft. By 1899, both jetties had been badly damaged by storms which displaced about 3,000 tons of granite capping blocks. During 1904-1905 the jetties were repaired, and the east jetty was extended 600 ft seaward. This work required 21,000 tons of riprap stone, 5,000 sq yd of mattress, and resetting 52 granite capping stones.
1940-1942	In 1940 the west jetty was repaired and extended 2,600 ft seaward parallel to the east jetty (1,000 ft apart). During 1941-1942 approximately 220,000 tons of stone was used in repairing the east jetty and to the -10 ft mlg contour, extending the east and west jetties 2,000 and 2,325 ft, respectively, to the 10-ft mlg contour. Prior to improvements, center-line elevations were from +1 to +3 ft mlg and from -2 to +4 ft mlg on the east and west jetties, respectively. The design sections (Figure 21, inset) for the extensions employed 5- to 10-ton cover stone and 25-lb to 4-ton core stone and were placed atop fascine mats ballasted with riprap. The east jetty was to have a crown elevation of +6 ft mlg and a crown width of 15 ft. Similar values for the west jetty were +4 ft mlg and 10 ft, respectively. The design side slopes were 1V:1.25H.
1952-1960	Center-line surveys, taken in 1952 and 1960, show a general settlement of up to 2 ft on the east jetty and 1 to 2 ft on the west jetty. The 1952 elevations were at, or slightly above, the design elevations used in the 1940-1942 improvements.
1962-1963	Both jetties were repaired, with most of the work carried out on their landward and seaward ends. At their seaward ends, 1,500 ft of the west jetty and 300 ft of the east jetty were repaired with 6- to 10-ton stone. An 800-ft-long section near the landward end of the east jetty was repaired with 150- to 500-lb riprap. The geometry of the repair sections was identical to that used on the 1940-1942 extensions. Cost of the repair was $98,500 using 5,000 tons of riprap and 4,000 tons of armor stone. Subsequent to this work, additional repairs were made to 1,150 ft of the landward end of the east jetty (including the previous repair area) and on the west jetty. Two sections totaling 215 ft were repaired, and the landward end was extended 50 ft (tie-in). The east jetty repair geometry consisted of a crown width of 10 ft at +6 ft mlg and 1V:1.5H

(Continued)

Table 10 (Concluded)

Date	Construction and Rehabilitation History
1962-1963 (cont.)	side slopes. The west jetty improvements were brought up to an elevation of +4 ft mlg. These repairs were made with 3,000 tons of 5- to 8-ton stone and rearranging 1,500 tons of stone at a cost of $48,000. These repairs made the effective lengths of the east and west jetties 8,200 and 7,700 ft, respectively.
1984	The landward 6,250-ft section of the west jetty was repaired, and its landward end was extended 400 ft (tie-in). The repairs were made with stone varying in size up to 3,500 lb (1,000-lb average for stone between 200 and 3,500 lb (85 percent of total)). The stone was to be placed to a crown elevation of +4 ft mlg, a 10-ft crown width, and 1V:2H side slopes. Stone size was based on a 4-ft design wave height. The purpose of the landward extension was to prevent continued erosion caused by river runoff. Prior to these repairs center-line elevations varied from +2- to +4-ft mlg. The cost and quantity of stone placed were $492,000 and 28,000 tons, respectively.

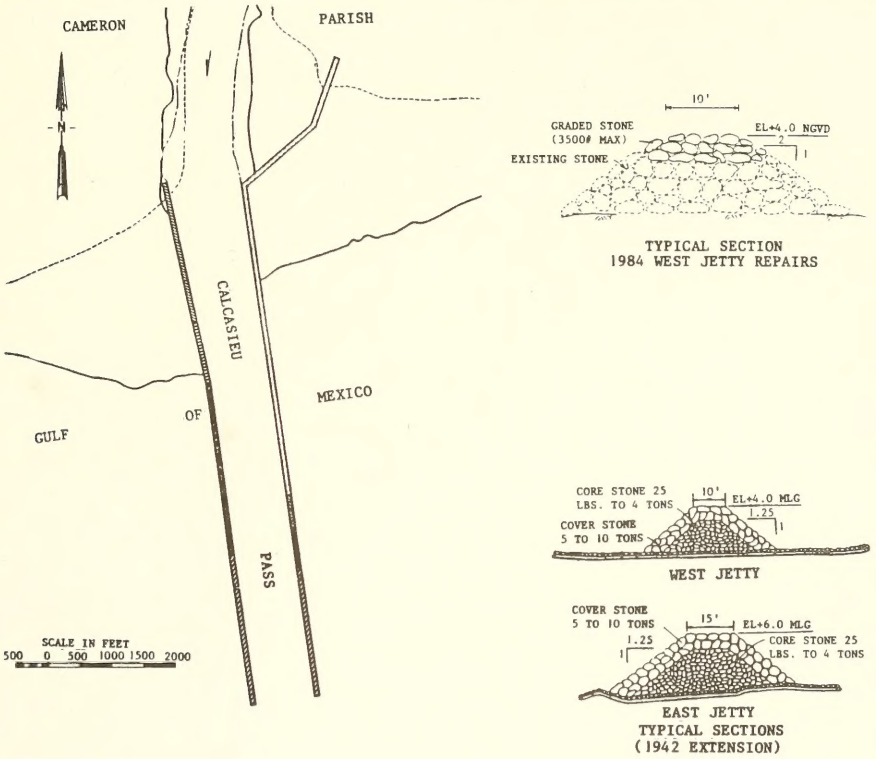


Figure 21. Plan view of Calcasieu Pass jetties and typical sections